SUPPLIER SELECTION BASED ON CAPABILITIES INDEX FOR MULTIPLE CHARACTERISTICS WITH ONE SIDED SPECIFICATION

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Abstract -- Raw materials are a significant requirement in the production process for manufacturing companies. In meeting the needs of raw materials for the production process, most manufacturing firms rely on suppliers. Supplier selection is an essential part of manufacturing companies. From several supplier selection criteria, quality is one of the fundamental standards and is used in supplier assessment. Selecting suppliers based on the quality of their products will have a positive impact on manufacturing companies, such as increased profits through reduced operational costs and increased market share. The problem faced is the lack of accuracy in choosing qualified suppliers. In this study will compare two suppliers at manufacturing companies and pick one that has a higher capability value. Supplier selection is made by using multiple characteristic capability index $C_{pu}$. The Supplier will be selected by comparing the ratio of two suppliers. Numerical calculations are performed on leather suppliers in shoe companies based on bursting quality, tear strength, tensile strength and elongation. The result of the calculation can be seen that supplier B is chosen as a better supplier. Characteristics of quality will affect the production process and application of shoes.

Keywords: Supplier selection; Quality; Capability index; Multiple characteristics; One-sided specification

INTRODUCTION
Manufacturing companies have relationships with many parties, one of which is a supplier. The Supplier is a company that provides material that cannot be provided by the manufacturing company itself (Mitrega, et al., 2017; Santoso and Besral, 2018). Manufacturing company must have the ability to choose the right supplier for succeeding. Supplier selection is a fundamental and critical decision for companies (Kuo and Lin, 2012; Rezaei and Davoodi, 2012; Wu et al., 2013). The decision in choosing a supplier impact directly on the competitiveness of the company and accelerates the company's response to market demand. Of the various criteria, quality is considered the most essential factor for supplier assessment (Liao et al., 2012).

The problem faced is the lack of accuracy in choosing qualified suppliers. The process capability index provides a numerical measure of the ability of a process to produce goods that meet specified quality requirements. The advantage of using index capability processes is more accurate and reliable when compared to traditional methods (Pearn and Wu, 2007).

Some authors have used index capability process with multiple quality. Pearn et al., (2013) considers the supplier selection problem for a normally distributed process with some independent characteristics based on the process capability index $C_{pu}$.

LITERATURE REVIEW
Process Capability Index Single Characteristic

Process capability index has been widely used to measure process capability and is essential for quality improvement activities. Some process capability index has been developed such as $C_p$, $C_{pu}$, $C_{pl}$, dan $C_{pk}$ (Kane, 1986).

$$C_p = \frac{USL - LSL}{6\sigma} \quad (1)$$

$$C_{pu} = \frac{USL - \mu}{3\sigma} \quad (2)$$

$$C_{pl} = \frac{\mu - LSL}{3\sigma} \quad (3)$$

$$C_{pk} = \min \left\{ \frac{USL - \mu}{3\sigma^2}, \frac{\mu - LSL}{3\sigma^2} \right\} \quad (4)$$

where USL and LSL respectively are upper and lower specification limits, $\mu$ is the process mean, $\sigma$ is the standard deviation of the process. Index $C_{cp}$ only measure the distribution of distribution (process precision), which only reflects the
consistency of product quality characteristics. Index $C_{pk}$ taking into account the magnitude of the process variance as well as the level of the average specification limits. $C_p$ and $C_{pk}$ used to measure the process with two sides of the specification, i.e., Lower Specification Limit dan Upper Specification Limit. $C_{pu}$ and $C_{pl}$ designed specifically for processes with one specification that only requires USL or LSL only. $C_{pu}$ is an index that measures the ability of a process smaller-the-better with Upper Specification Limit (USL), while $C_{pl}$ is an index that measures the ability of a process larger-the-better with Lower Specification Limit (LSL).

**Process Capability Index Multiple Characteristics for One Side Specifications**

Wu and Pearn (2005) discusses multiple characteristic processes for one-sided specifications with upper specification limits and proposes a process capability index for smaller the better as,

$$C_{pu} = \frac{1}{3} \phi^{-1} \left( \prod_{j=1}^{v} \phi (3C_{puj}) \right)$$  \hspace{1cm} (5)

where $C_{puj}$ show the value $C_p$ of characteristics $j_n$ for $j = 1, 2, \ldots, v$ and $v$ is the number of characteristics. The relationship between the index $C_{pu}$ and overall process yield $P$ can be defined as,

$$P = \prod_{j=1}^{v} P_j = \prod_{j=1}^{v} \phi (3C_{puj}) = \phi \left( 3C_{pu}^T \right)$$  \hspace{1cm} (6)

Overall process yield in parts per million (PPM) can be given as follows,

$$\text{yield} = 10^6 \times \phi \left( 3C_{pu}^T \right)$$  \hspace{1cm} (7)

For every single characteristic, the value $C_{puj}$ can be estimated using natural estimator,

$$\hat{C}_{puj} = \frac{(USL_j - \bar{x}_j)}{s_j}, \; j = 1, 2, \ldots, v$$  \hspace{1cm} (8)

where $\bar{x}_j = \text{mean sample characteristics } j_n$, $s_j = \text{standard deviation of sample characteristics to } j_n$ and estimators of $\hat{C}_{pu}$ defined as,

$$\hat{C}_{pu} = \frac{1}{3} \phi^{-1} \left( \prod_{j=1}^{v} \phi (3C_{puj}) \right)$$  \hspace{1cm} (9)

Pearn et al. (2012) calculates the asymptotic distribution $\hat{C}_{pu}$ using Taylor expansion for the following multiple variables,

$$\hat{C}_{pu}^T \approx N \left( C_{pu}^T, \frac{1}{9n} \left( \frac{C_{pu}^T}{2n} \right)^2 \right)$$  \hspace{1cm} (10)

The above method can be used for processes that only have many lower specification limits (LSL) with exact mathematical transformation. The previously mentioned results can be implemented to compare two suppliers with index values $\hat{C}_{pu1}^T$ and $\hat{C}_{pu2}^T$.

Then Pearn & Wu (2013) shows the ratio of 2 (two) natural estimators as follows,

$$R = \frac{\hat{C}_{pu2}^T}{\hat{C}_{pu1}^T}$$  \hspace{1cm} (11)

Thus, the test statistic distribution R is the result of two normally distributed random variables and therefore is related to the Cauchy distribution. Using the Jacobian transformation and the convolution approach, the probability density function $R$ can be obtained as,

$$f_R(r) = \frac{1}{2\pi\sigma_1\sigma_2} \left( 2\sigma_1 r \exp \left( \frac{-r^2}{2\sigma_1^2} \right) + \mu_r \sigma_1 \sqrt{2\pi} \left( 1 - 2p \left( \frac{\mu_r}{\sigma_1} \right) \right) \right)$$

$$\times \exp \left( -\frac{1}{2} \frac{\mu_r^2}{\sigma_1^2} + \frac{\mu_r^2}{\sigma_2^2} \right)$$  \hspace{1cm} (12)

where,

$$\mu_r = C_{pl1}, \mu_r = C_{pl2}, \sigma_1 = \frac{1}{\sqrt{2n}}, \sigma_1 = \frac{1}{\sqrt{2n}}, C_{pl1} = \frac{C_{pl1}}{2n},$$

$$\mu_r \sigma_1 = \frac{\mu_r}{\sigma_1} = \frac{\mu_r \sigma_1 + \mu_r \sigma_1}{\sigma_1 + \sigma_1} = \left[ \frac{1}{R_1^2} \frac{r^2}{\sigma_1^2} \right] \left[ \frac{1}{\sigma_1^2} \frac{r^2}{\sigma_1^2} \right]$$  \hspace{1cm} (13)

**RESEARCH METHODS**

The histogram is made with a one-sided specification limit and a normal probability plot of skin quality data collection with bursting, tear strength, tensile strength and elongation characteristics for supplier A and supplier B to determine the position and distribution of data. The next step is to calculate the value of $C_{pl}^T$ from each supplier $C_{pl1}^T$ and $C_{pl2}^T$.

$$\hat{C}_{pl} = \frac{1}{3} \phi^{-1} \left( \prod_{j=1}^{v} \phi (3C_{puj}) \right), \; i = A, B$$  \hspace{1cm} (14)
\[ C_{pl_i} = \frac{\mu_i - LSL}{3\sigma_i}, \quad i = A, B \]  

where,  

- \( LSL \): lower specification limit  
- \( \mu_i \): mean sample  
- \( \sigma_i \): standard deviation sample

To compare the yield process of two suppliers, a hypothesis test was performed for the ratio of two indices yields as follows,

\[ H_0 = \frac{C_{pl2}^T}{C_{pl1}^T} \leq 1 \]  
\[ H_1 = \frac{C_{pl2}^T}{C_{pl1}^T} > 1 \]  

After the hypothesis then calculate the ratio of statistical tests R based on the standard approach to the distribution \( C_{pl}^T \)

\[ R = \frac{C_{pl2}^T}{C_{pl1}^T} \]  

Analyze is done to test ratio and critical value with supplier requirement \( C_{pl}^T = 1.30 \). For supplier A and supplier B is calculated the mean sample, standard deviation sample, an index \( C_{pl}^T \) for each of the characteristics obtained from the data with \( n_1 = n_2 = 150 \)

The following hypotheses can be used to select suppliers,

\[ H_0 : C_{pl2}^T \leq C_{pl1}^T \]  
\[ H_1 : C_{pl2}^T > C_{pl1}^T \]  

So that can be obtained which supplier is better and will be prioritized.

The step of the experiment:

1. Bursting Test
   
   Cut test specimen with a diameter of 4.5 cm. Attach it to the lastometer testing machine. Observe the specimen until it cracks.

2. Tear Strength
   
   Cut test specimens with the slit parallel to the long direction of the material (backbone direction for leather and selvage (warp) or machine direction. Mark the along direction of all the test specimens. Zero the tensile tester force measuring system and move the jaws together to enable the test specimen to be fitted. Hold the test specimen flat between the jaws of the tensile testing machine so that the slit is aligned and parallel with the axis of the machine. Clamp one of the legs in the lower jaw and then fold the other leg upwards through 180° and clamp it into the upper jaw. In each case ensure that the end of the leg is parallel with the clamping edge of the jaw and that the slit is positioned in the axis of the tensile tester.

3. Tensile Strength
   
   Cut the specimen with a dumbbell shape. Attach it to the tensile test machine.

4. Elongation
   
   The procedure follows a tensile test by installing an extensometer.

RESULTS AND DISCUSSION

In this study using bursting quality data, tear strength, tensile strength and elongation of two suppliers. Each supplier has 150 data for each quality characteristic. The minimum specification limit of each quality characteristic for bursting = 20 kg/cm², tear strength = 10 Newton, tensile strength = 60 Newton, dan elongation = 70%.

The processing of the leather itself determines the quality characteristics of the leather. Characteristics of quality bursting, tear strength, tensile strength and elongation will significantly affect the production process and application of the use of shoes. In this study using the limit with Lower Specification Limit (LSL). The following is presented data from each supplier.

![Histogram of Bursting Supplier A](image)
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Figure 2. Probability plot of Bursting supplier A

Figure 5. Histogram of Tensile Strength supplier A

Figure 3. Histogram of Tear Strength supplier A

Figure 6. Probability plot of Tensile Strength supplier A

Figure 4. Probability plot of Tear Strength supplier A

Figure 7. Histogram of Elongation supplier A
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Figure 8. Probability plot of Elongation supplier A

Figure 11. Histogram of Tear Strength supplier B

Figure 9. Histogram of Bursting supplier B

Figure 12. Probability plot of Tear Strength supplier B

Gambar 10. Probability plot of Bursting supplier B

Figure 13. Histogram of Tensile Strength supplier B
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From Fig. 1 to Fig. 16 shows the histogram with lower specification limits and standard probability plots with Anderson-Darling test from each supplier A and supplier B data. From histogram data, it can be seen that some quality tensile strength values in supplier A do not meet the requirements (outlier).

Based on the above measurements, the sample means, sample deviation standard and capability index value $C_{pl}^T$ for each supplier can be calculated.

For supplier A, the sample mean, the sample deviation standard of each is already known, and the first step is to calculate the value $C_{pl}$ for bursting, tear strength, tensile strength, dan elongation use the following formula,

$$C_{pl} = \frac{\mu - LSL}{3\sigma}$$

The result of the calculation $C_{pl}$ for supplier A as follows, bursting = 2,2654; tear strength = 2,8004; tensile strength = 0,5287; elongation = 2,0563. Then calculate the value for $C_{pl}^T$ as follows,

$$C_{pl}^T = \frac{1}{3} \phi^{-1} \left( \prod_{j=1}^{v} \phi \left( 3C_{p_{uj}} \right) \right)$$

= 0,5286

As for supplier B, the sample mean, the standard deviation of each sample is known, and the first step is to calculate the value of $C_{pl}$ for bursting, tear strength, tensile strength, and elongation using the following formula,

$$C_{pl} = \frac{\mu - LSL}{3\sigma}$$

The result of the calculation $C_{pl}$ for supplier B as follows, bursting = 2,3815; tear strength = 2,9828; tensile strength = 1,2505; elongation = 2,2147. Then calculate the value for $C_{pl}^T$ as follows,

$$C_{pl}^T = \frac{1}{3} \phi^{-1} \left( \prod_{j=1}^{v} \phi \left( 3C_{p_{uj}} \right) \right)$$

= 1,2505

The hypothesis used to compare from two suppliers is as follows,

$$H_0 = \frac{C_{pl}^{T}_{p_{B}}}{C_{pl}^{T}_{p_{A}}} \leq 1$$

$$H_1 = \frac{C_{pl}^{T}_{p_{B}}}{C_{pl}^{T}_{p_{A}}} > 1$$

While the calculation of R statistic test ratio based on the normal approach to the distribution $C_{pl}^T$ as follows,
The critical value of $\alpha = 0.05$ with the sample value $n = 150$ is 1.8047 (Pearn et al., 2012). From the above ratio, values note that $R > c_0$; $R = 2.3656 > 1.8047$ then $H_0$ will be rejected, and it can be concluded that the capability index of the process differs significantly by $\alpha = 0.05$.

Then the hypothesis to select a supplier based on the capability index $T_{pl}$,

$H_0 : C^T_{plB} \leq C^T_{plA}$

$H_1 : C^T_{plB} > C^T_{plA}$

From the results of the capability index $C^T_{plB}$ obtained $C^T_{plB} = 1.2505 < C^T_{plA} = 0.5286$, then $H_0$ rejected, so from these results can be derived a better supplier B and will be prioritized.

CONCLUSION

Effective supplier selection will significantly determine success for manufacturing companies. From several supplier selection criteria, quality is one of the preferred criteria in supplier assessment. Selecting a supplier based on the quality of its product will have a positive impact on the manufacturing company.

Capability process index is an important criterion used in the manufacturing industry to measure process performance. Capability process index $C^T_{pl}$ provides a measure with a one-sided specification limit for normal processes and provides a precise numerical measurement of process performance on suppliers. Higher accuracy to assess the two suppliers is obtained using the capability index $C^T_{pl}$. From the above calculation obtained capability index $C^T_{plB} = 0.5286$ and $C^T_{plA} = 1.2505$. Process capability index $C^T_{plB}$ greater than $C^T_{plA}$, so that supplier B is better to choose.

REFERENCES


